LITTLE CLIMATES

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Verne N. Rockcastle

If you looked at a weather map for all of the United States, you might find that on a day when the temperature was 100° F. in Texas, it was only 50° F. in Alaska. On another day, it might be below zero in Maine, but above freezing in Florida. Would it surprise you to learn that these temperature extremes may occur on the same day near your home or school? In the microclimate (the layer of air near the ground) the variation in temperature, humidity, wind speed, precipitation and other weather factors is as great as it is across our country. In the microclimate, you may find the same difference within inches that you would find between Texas and Alaska!

WHAT IS A MICROCLIMATE?

When the Weather Bureau observers read the temperature or the humidity, they read it in an instrument shelter at eye level. Sometimes instrument shelters stand on the ground, and sometimes on a roof top. Slotted sides on the shelter let the air circulate around the instruments, but the shelter shades and protects the instruments from direct sunlight or cold clear skies. By avoiding extremes that exposure would cause, the observers get what they call representative readings.

Representative readings from an instrument shelter do not indicate what may be happening at surfaces, however. When the temperature in an instrument shelter is 80° F. and the day sunny, it may be over 100° F. at the ground surface. Countless small animals and plants living in the layer of air near the ground (the microclimate) are exposed to all the extremes that occur there.

Suppose that it is a cold, clear winter morning where you live. The radio announcer says that the temperature is 10° F. You look at the thermometer on your back porch and it indicates 5° F. Another person looks at the thermometer outside his living room window and

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soften. Scientists who understand these conditions have helped to develop roofing materials that can stand these severe microclimates.

Automobile tires must be able to withstand both the heat produced by friction and the high temperatures of pavements in summer. Blacktop pavements, especially, become extremely hot in bright summer sunlight. These same pavements, however, help to melt snow and ice in winter because they absorb the sun's energy better than light colored surfaces.

Chemical companies have had to design a special paint for marking the lines on blacktop pavements because of the high and low temperatures that the paint must withstand. Ordinary paints tend to decompose when the blacktop surface becomes very hot under the blazing sun.

On a cold winter night, when most things contract as the temperature falls, the concrete and steel in bridges, the wires between power and telephone poles, the blocks of concrete on the sidewalk, and even the ice on a pond or a lake contract much more than the representative temperatures of the Weather Bureau or your radio station would indicate.

Almost any material that is exposed to the sun's rays or to the night sky exists in a microclimate of extremes. When these materials wear out rapidly or fail, remember that a part of the failure or wear is caused by conditions that we seldom feel because we are insulated from them by houses, shoes, socks, suits, skirts, hats, and gloves.

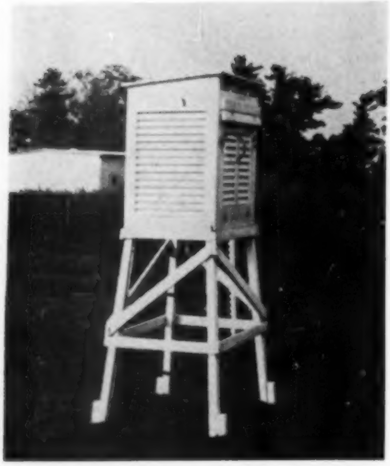
WHAT MAKES A MICROCLIMATE?

Radiation

For about half of each day (more in summer and less in winter) sunlight streams down to our part of the earth. This *incoming radiation* is mostly in the form of light, but it quickly changes to heat when it strikes the earth's surface. Some of it warms the land. Some of it warms the grass, the trees, and the buildings. Some of it evaporates water from the oceans, from ponds, and from wet soil. Some of it is used to make food in plants. Some of it does not do any of these things; it is reflected back into space without being absorbed.

In general, dark-colored surfaces absorb more of the sun's energy than do light-colored surfaces. Blacktop pavement, dark cars, dark roofs, dark clothing, dark soils, and even the cinders spread on snow and ice absorb much of the sun's energy that strikes them.

Light-colored surfaces such as snow and ice, clouds, bodies of water, sand, white houses, white or cream-colored cars, aluminum foil, and similar surfaces reflect much of the energy that falls on them. You can see this for yourself by resting



This Weather Bureau instrument shelter keeps readings representative.

sees a temperature of 15° F. Still another person living in a hollow a few miles from town may find that his thermometer reads –10° F. Which is correct? All four may be right!

Because each of the thermometers is in a different location, each represents a different microclimate. The Weather Bureau tries to place its instruments so they will not be affected by various microclimates, although the very microclimates that the official Weather Bureau instruments avoid offer some of the most interesting studies.

WHY ARE MICROCLIMATES IMPORTANT?

If you had to live without clothing or a house, you would be at the mercy of the microclimate around you. On hot summer days you would almost roast; in mid-winter you might freeze to death; most of the time you would be uncomfortable. However, your clothing and your house protect you from the extremes of climate near the ground.

Some animals that cannot regulate their temperature or create artificial protection as we do have natural adaptations or habits to protect them from the microclimate. You will read more about them on page 29.

Young tomato and cabbage plants, orchards, strawberry patches, and other plants upon which we depend for food are almost directly controlled by the microclimate in which they grow. Sometimes plant growers cover plants such as cabbages with paper caps to provide artificial protection. Usually, however, the success of a crop depends upon the weather where the plants are growing—the microclimate.

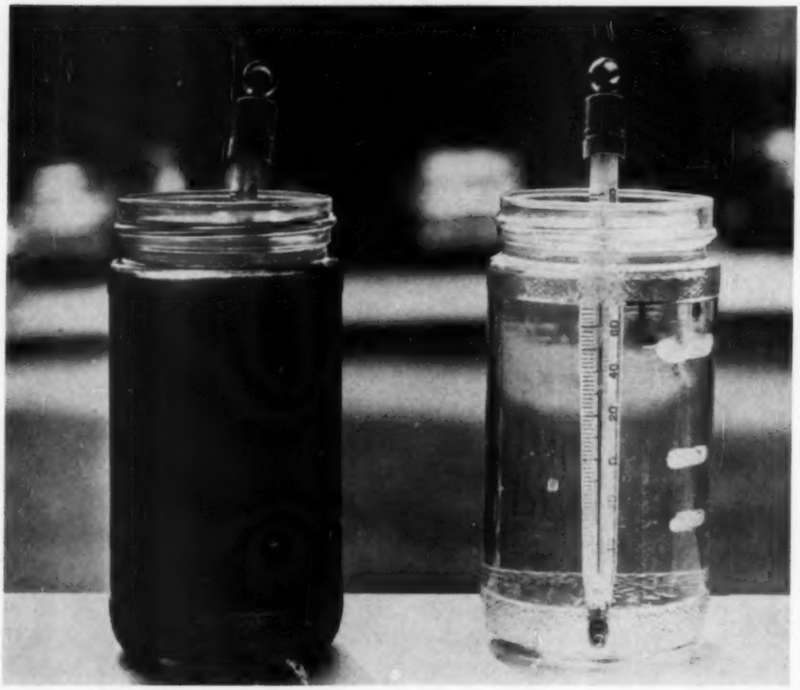
Farmers may use the extremes of climate near the ground to help them control insect pests. By plowing fields in the fall, they expose many burrowing insects to the rigors of winter. Numbers of these insects die from exposure, providing an effective and inexpensive control.

Microclimates are important for non-living things, too. Roofing materials, for example, must withstand temperatures that we could never tolerate. A dark roof in direct summer sunlight becomes unbelievably hot. The high temperature makes the material expand as well as

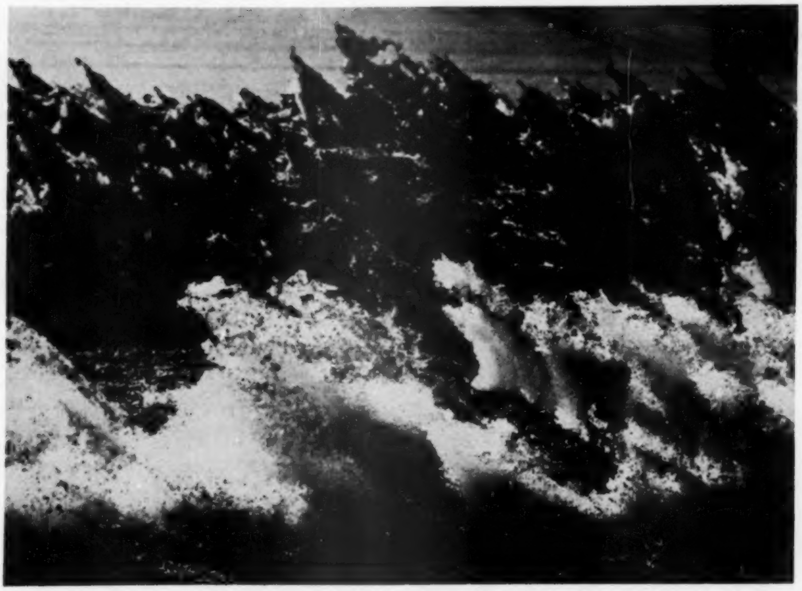
your hand on the hood or the top of a dark car that has stood in the sun for some time, then on the hood or the top of a light car that is also in the sun. Which of the two is cooler?

You can test this difference in absorption of radiation in another way. Blacken a can or a bottle by carefully rotating it in a candle flame or by spraying it with flat black paint. Paint a similar container with aluminum or white paint, or wrap it with aluminum foil. Fill each with an equal amount of water at the same temperature. Put a thermometer in each container and set them in the sunlight. After an hour, read the temperature of each container. Which has absorbed the greater amount of energy?

The temperature difference between light and dark surfaces is apparent where blacktop and concrete pavements meet. Find a place where a blacktop drive meets a concrete sidewalk, remove your shoes and



In the sunlight, the water in the blackened jar became much warmer than that in the unblackened jar.



Cinders melting their way through snowdrifts left peaks pointing towards the sun. Can you figure out why?

socks, and stand with a bare foot on each surface. How do they compare?

By filling the two halves of a stocking box or a handkerchief box with sand of two different colors, you can test the absorption of the sun's energy by light and dark soils. Lay a thermometer just under the surface of the soil in each half of the box, and set it in the sun. Within a half hour you should be able to see a great difference in the two temperatures.

Along the shores of several New York State lakes and some of the Great Lakes, there are streaks of dark matter mixed with the white sand. These dark streaks are magnetite, an iron ore that has eroded from nearby deposits and has been washed up on the shore. If you find one of these magnetite streaks on a sunny summer day, try standing on it with your bare feet. Sometimes it will be so hot that you cannot rest your feet on it, but on the white sand the temperature is not nearly so high.

Even an object as small as a cinder on the snow will show a different rate of heat absorption from the snow around it. Above is a picture of snowdrifts along a curb several days after a cinder truck had passed. Each black cinder absorbed enough of the sun's energy to melt

its way down into the snow. As it melted and formed a little depression, only the north end of the cinder remained in the sunshine. The rest of the cinder lay in the shadow of the depression it had made in the snow. In this way, the cinder was warmer at one end than at the other, and melted a sloping depression in the snow. After a time, the unmelted snow looked like a series of little mountains, all pointing in the direction of the sun. In the valleys lay the cinders. Some scientists have proposed a similar treatment for melting glaciers. Their proposal is to sprinkle finely powdered black material over the snow and ice so it will absorb, rather than reflect, the sun's energy and start melting.

Tree trunks, and even little stalks of grass sticking up through the snow can absorb enough energy from the sun to melt a little space around them. The snow itself is a good reflector of the sun's incoming radiation, but darker objects in and on the snow may absorb enough energy to melt some places, while others remain unmelted.

Although the sun's energy reaches our section of the earth only part of the day, the earth's surface is sending some energy into space all the time. Radiation does not leave in such tremendous quantities as it comes in, but it leaves constantly. When the sun is shining, more energy comes in than goes out. Then our part of the earth warms. At night, when the sun no longer sends us energy, the earth cools as it sends some radiation back to space. The earth's outgoing radiation probably does not change very much from day to day, but each day the sun sends a tremendous amount in to balance what the earth loses.

Imagine that the sun rises over some land that has fields, woods, lakes, houses, roads, and even a discarded white paper lying on the grass. As the sun's energy pours in on all these things, the fields, woods, houses, roads, and even the white paper grow warmer. They warm at different rates, however, because some, like the paper and the sandy shores of the lakes, reflect much of what strikes them. The dark roads become warmer than the light ones. The dark fields become warmer than the green ones. The green ones become warmer than those that are yellow with wheat. Each object warms according to the amount of the sun's radiation it absorbs

Late in the afternoon, as the sun gets lower in the sky, it sends less and less radiation to this part of the earth. (Other parts now get the sun's energy.) As night comes on, the fields, woods, houses, roads, and even the white paper cool as they send their energy back into space. However, they cool at different rates, partly because they had received different amounts of energy from the sun, and partly because they are not equally good radiators. The darker things radiate better

than the light ones. The paper and the sand send very little energy back to space. This unequal absorption of energy, and the unequal rate at which surfaces on the earth send their energy back into space is probably the most important single cause of microclimates.

Conductivity

Surfaces differ in the rate at which absorbed energy spreads through them. Metallic surfaces conduct their heat rapidly, but surfaces of wood, plastic, and glass are poor conductors of heat.

You can see how different the conductivity of common classroom objects is by resting your hand on a number of surfaces to test the temperature. When you put your hand on a metal filing cabinet, on the handle of a door, or on a slate blackboard, these objects feel cool because they conduct heat away from your hand rather quickly. Other objects such as a wooden desk top, an eraser, or a piece of cloth feel warm because they conduct very little heat away from your hand.

Now place a thermometer against each of these objects. Is there really a difference in temperature, or did you imagine the difference because the conductivity of the objects varied? Is your hand a good indicator of temperature?

When a poor conductor such as a piece of wood is exposed to the sun's radiation, a very thin layer of

The concrete of this New Jersey turnpike conducts enough heat from the underlying soil to delay freezing; the bridge cannot.

its surface absorbs most of the energy. Wood is such a poor conductor of heat that very little of the energy striking the surface moves down into it. When you put your hand on the wood, it feels warm but not hot, even though its surface temperature may have been very high. Wood is such a poor conductor that much of its heat cannot get to your hand.

A piece of metal lying in the sun, however, can conduct its heat to your hand quickly, and more can flow from other parts of the metal. As a result, an object that is a good conductor may seem to be hotter than one that is a poor conductor. Actually, the poor conductor lying in the sun may have a higher surface temperature, but less heat spread throughout.

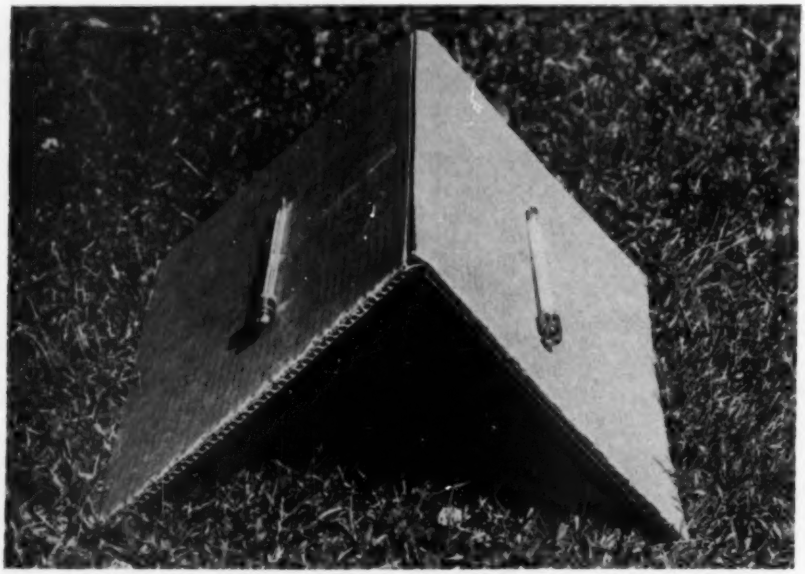
At night a poor conductor usually has a colder microclimate around it than a good conductor because the poor conductor cannot replace

the heat it loses from its surface by radiation. The good conductor can quickly bring up more heat from parts below the surface, or from the soil beneath it. This difference in conductivity may help to explain why a board lying on the ground will frost over more quickly than a flat stone lying nearby, or why dead leaves will frost over more quickly than a piece of metal. Both the stone and the metal can get more heat from the soil beneath them, but the wood and the leaves cannot. You can read more about interesting effects of radiation and conductivity on frost formation on page 26.

Shape of the surface

If all surfaces were horizontal and perfectly smooth, microclimates would not be so varied. There are all degrees of slope and these slopes can face in almost any direction. Some slopes are really hillsides. Some are merely the sides of footprints, or even the rounded portion of a single leaf vein or the sides of scratches so small that you cannot see them without the help of a magnifier.

Sloping surfaces may face north, east, south or west. On some the sun may sometimes shine at right angles. On others, the sun scarcely shines at all. This tilting of the sur-



How much difference in temperature do you find on the two sides of a little cardboard hill such as this?

face, and the direction in which it faces greatly affect the amount of radiation absorbed or sent back into space.

To see this for yourself, construct an artificial hill from a piece of cardboard. On one side tape a thermometer parallel to the ground. Shade the bulb with a tiny rectangle of white cardboard to prevent the sun from shining directly on it. Place a second thermometer on the other side of the hill. Stand the hill with one side facing the sun; the other side will face away from the sun. After a half hour, examine the two thermometers. How do the temperatures compare?

Direct temperature measurements will show the effect of large-scale irregularities such as hills. Small irregularities may have equally pronounced effects, but their small size makes it difficult to use thermometers for determining their temperature and other differences. For this reason, scientists often use indirect evidence such as frost and dew to show how the microclimates of small irregularities differ. You will read more about this on page 27.

Wind and air drainage

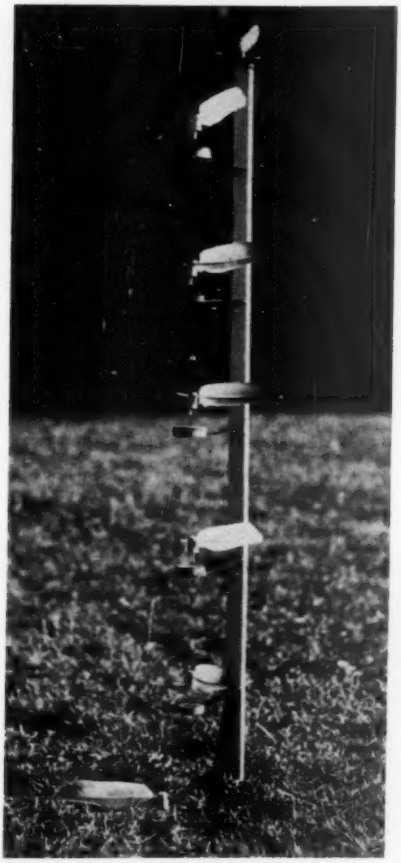
Have you noticed how the wind decreases when you walk from a field into a woods? The wind decreases in the same manner as you move down toward the grasstops, or into the weeds. Above a lawn or a grassy meadow the wind may be blowing noticeably, but in the grass or the weeds, it may be almost calm.

The calm that prevails in most microclimates helps to increase the extremes of climate found there. If the wind were strong in a microclimate, then temperatures would not rise so high nor fall so low as they do. Wind makes the cold places warmer, and the warm places cooler by mixing warm air with cold air.

At night, when surfaces cool by radiation to space, the air next to them cools by contact. Where there are little hills and depressions, the cold air next to the sloping surfaces becomes heavy and slowly flows downhill. Small depressions fill first, then overflow, and the cold air pours into bigger and bigger valleys. This is most noticeable on clear, calm nights in fall and winter. Soon a valley is filled with air that has flowed down from surrounding hillsides.

The puddling of this cold air in low places promotes the formation of frost and dew, or even layers of fog. Sometimes crops may freeze in one of these cold air puddles, while other crops on hillsides escape with little or no damage.

Sensitive wind vanes will help to show these subtle currents of cool air flowing down even a slight slope. To make one of these vanes, seal over the end of a small diameter glass tube as shown. When it cools, cut the sealed tube to about one inch in length. Fire-polish the cut



Notice how the shallow downslope wind has turned the bottom feather-vane, but has not reached the rest.

feather, but it has not yet turned the ones above.

You sometimes can see air drainage on hillsides in autumn when the smoke from leaf fires flows downhill in late afternoon or early evening on a calm, clear day. The hillsides of Cayuga Lake, near Cornell University, often show little smoky streams running toward the lake as farmers burn piles of leaves and weeds on the hillsides. The smoke particles that settle in the valley promote the formation of valley fog, which forms when cold air settles in a hollow and cools below the condensation point.

Campers sometimes feel cold air drainage at a campsite. The hollows that seem protected from the wind, and look inviting at mid-day, may be collecting places for cold air that moves down surrounding slopes at night. Often a hollow shows frost in early morning, but the slopes above the hollow are frost free.

Insects that hover in swarms are sensitive to these microclimates and quickly leave the cold pockets and move to warmer spots. Automobile windshields become insect-spattered much more quickly in the warm air above the hilltops than in the cold air of the hollows.

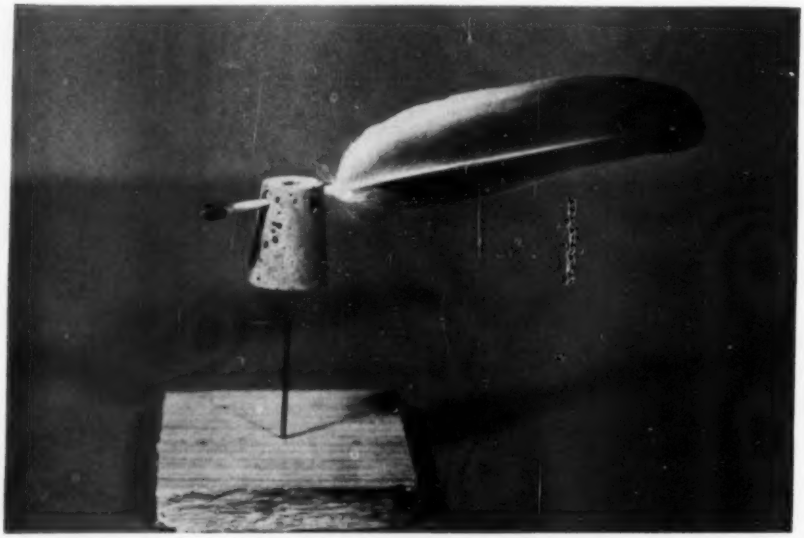
Humidity

The relative humidity near the ground varies from extremely high to extremely low values just as temperature does. Near the grasstops, or where green vegetation grows, the soil is shaded from the sun. In addition, leaves give off water vapor by transpiration, and a blanket of water vapor is nearly always present around green plants. In this high humidity live many invertebrate animals.

Rotate the glass tube evenly to make a good bearing.

end to make it blunt. Insert this glass bearing in a hole in a cork and put a straight feather crosswise through the cork just above the bearing. Set the assembly on a long needle. It will turn freely at the slightest breeze. To make it even more sensitive, wind a bit of strip lead or wire around the exposed feather shaft as a counter-balance.

Several of these feathervanes set on broken or discarded hacksaw blades in slots in a wooden upright will help to show when the wind shifts at different levels as the cool air becomes deeper. The picture on page 13 shows that cool air moving downslope has turned the bottom



This feathervane will show the slightest air movements either out of doors or in the classroom. Try it on the floor in front of an opened refrigerator door.

Dew is formed when the leaf surfaces and other surfaces cool because they radiate their heat into space at night. This makes their surfaces so cold that the water vapor around them condenses just as it does on the outside of a pitcher of ice water. Water of guttation comes from inside the plant. Dew comes from outside the plant.

You can tell the difference between dew and water of guttation by putting a drop of each on a clean piece of glass and letting the drops evaporate. Because it is distilled water, dew evaporates with almost no trace left on the glass. When water of guttation evaporates, it leaves a whitish deposit from the chemicals that were dissolved in it.

Scientists have learned to measure the humidity in small spaces of the microclimate in several ingenious ways. They know that some chemicals such as concentrated sulfuric acid absorb water readily. These chemicals increase slightly in volume as they absorb water. One scientist has perfected a technique for making tiny glass capillary tubes which he fills with concentrated sulfuric acid. When these are laid down under leaves, or next to the soil, the acid in the tube absorbs water and bulges slightly at the ends of the tube. The scientist can tell the humidity from the amount of the bulge.

Another scientist has perfected a technique for coating a piece of glass with a metallic film that will conduct electricity. Then he makes a tiny scratch to divide the metallic film in two sections. He coats the scratch with a chemical whose conductivity varies with the humidity. By means of sensitive electrical meters he can tell the humidity by the amount of electricity flowing across the scratch.

Precipitation

In some parts of the microclimate around your home or school there is little more precipitation than in Death Valley. In other parts, precipitation may be twice what the Weather Bureau records annually. Precipitation may be lowered by obstacles such as hills, buildings, trees, fences, or boulders. It may be increased by these same obstacles, depending upon how they are placed, and where you measure the precipitation.

To measure the precipitation in various parts of your microclimate, you can make a simple rain gauge from a tin funnel, a number-five can, and a small juice can. Set the smaller can in the bottom of the larger can and rest the funnel in the opening above. The rain that falls into the funnel is concentrated into a smaller space when it pours into the smaller can, so the rain gauge magnifies the rainfall. If the funnel has four times the area of the smaller can, then the rainfall looks four times as great when you measure its depth in the smaller can.

Over a paved surface or a sandy soil that is free of vegetation, however, the temperature may rise very high without this blanket of water vapor. Then the relative humidity is very low; many plants and animals cannot live where it is so dry.

Among the grasstops of the school lawn the relative humidity stays close to 90 percent or higher. On top of the sidewalk, it is probably below 25 percent. At five or six feet above the sidewalk, however, the dry air and the moist air become well mixed. Here the relative humidity is about the same as it is above the grass. Large differences occur only close to the surface.

Sometimes the relative humidity near the surface is so high that the water given off by plants cannot evaporate, and it stands in droplets along the edge of the leaves. Some plants such as strawberries and grapes seem to ooze water in droplets along their leaf margins. This *water of guttation* is seldom seen in the daytime. It is common only on calm, clear nights when temperatures are low, wind speed is near zero, and the relative humidity near the plants is close to 100 percent.

When the humidity was high, water of guttation appeared along the edges of these grape leaves. How does it differ from dew?

Irregularities in the soil surface may cause puddles to form here and there, creating miniature lakes that moderate the microclimate around them. Take the temperature of some puddles at different times during the day and compare them with the temperatures of the microclimate nearby to see how these little lakes of rain water differ from the land surface around them.

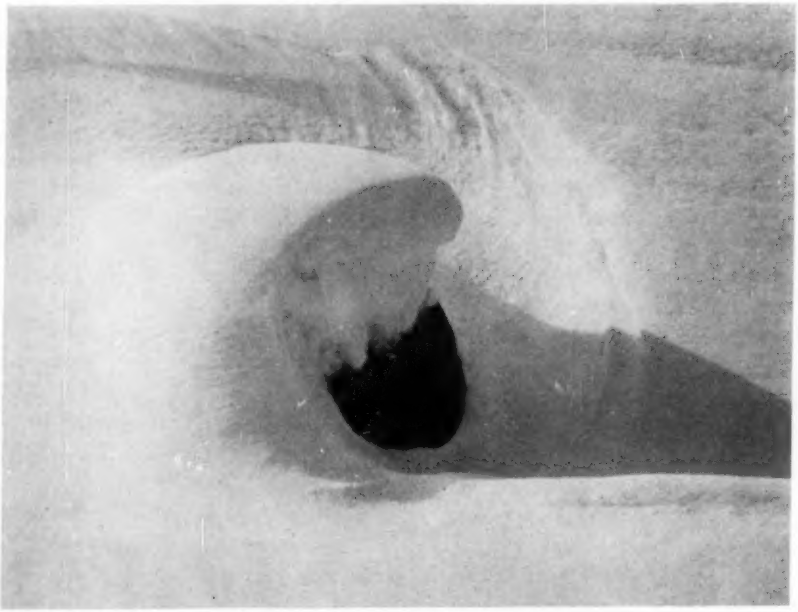
SOME INTERESTING MICROCLIMATES

Little deserts

Footpaths, sidewalks, driveways and road shoulders represent deserts on a small scale. To see that they have extremes of climate that are greater than grassy plots or wooded areas, put a thermometer bulb on or just under the soil in a path or driveway where the grass is worn away. Can you see that the temperature is much higher than where the soil is protected by grass, leaves, or trees? A playground has many such areas where the temperature rises very high in the daytime, and cools very much at night.

On these hard-packed areas, little of the rain that falls soaks in. Here, where the temperature may rise well above 100° F. during a sunny day, and fall well below freezing when other areas remain above freezing, the microclimate is almost devoid of visible animal life. Snails, earthworms, many insects, and other invertebrates that prefer more moist locations never visit these little deserts.

Three pupils examine the temperature of a little desert beside their school playground. It was 125° F. here!



The snow depth on one side of this boulder is several times as great as on the other.

To calibrate your rain gauge, find the areas of the funnel and the smaller can. You can do this by comparing the *squares* of their diameters. If the funnel is four inches in diameter, and the smaller can is two inches in diameter, the ratio of their areas is 4^2 to 2^2, or 4:1. Your calibration stick should show only ¼ inch of rain if the water is one inch deep, ½ inch of rain if the water is two inches deep, and so on.

Where buildings, overhanging roofs, trees and fences protect some parts of the soil from rain and snow, little or no precipitation falls. In other places, where a gutter drips frequently, or where the blowing rain and snow strike a wall and run down, the precipitation that reaches the soil may be tremendous.

A snow fence may cause the precipitation on one of its sides to be as high as the record snows of the Rockies. On the other side, the soil may be almost bare during the winter. On one side of the fence a heavy snow cover may delay the growth of plants, but on the bare side plants may resume growth much earlier. How would the daytime and nighttime temperatures under the snowdrift and on the bare ground differ?

3. Temperature—put thermometers at the soil surface of a little desert and a grassy plot. Compare their daytime and nighttime readings.
4. Animal traces—what evidence can you find of animals in a little desert compared with a nearby grassy plot? Look for the animals themselves, their castings, their burrows, their tracks, and other traces. How do the two areas compare in animal life?

Grassy jungles

Near the little deserts may be microclimates approximating the jungles of the tropics. On a sunny day in early fall or late summer, the temperature of these grassy jungles may soar to 100° F., with a relative humidity of 90 percent—conditions that you might expect in a standard instrument shelter in central Panama, in the Philippines, or in Burma. Here animal life is far more abundant than in the little deserts. You can see a number of small creatures if you search the grass carefully on your hands and knees.

Among the grass stems the wind velocity is almost zero. No matter how hard the wind blows high above the grass, the animals that live in this miniature jungle are little disturbed by it. They live in a tiny forest of dense greenery. The

In the dense, humid grassy jungle you can find earthworm burrows such as this. How many other animal traces can you find?

Seeds that settle on a little desert seldom take root. The wind on these places is strong enough to blow most seeds to the edge of the desert, so they do not stay on the bare soil long enough to germinate. Rain runs off the little desert and may carry the seed along with it. What rain does fall there evaporates quickly if it does not run off. As a result, little deserts are not quickly taken over by seeds.

Sometimes plants that grow at the edge of little deserts will spread their leaves over the desert. Knotweed is one of the hardy plants that spreads over paths and even concrete walks. It roots in the soil beside walks and paths, but sends long stems over the barren surfaces. These stems may provide shade and windbreaks for the little deserts. Then seeds do not blow away so quickly, and rain does not run off so quickly. Some seeds can sprout and begin to change the little desert to a different kind of climate. Look along the walks and paths near your school and see if you can find knotweed and other plants that help to change the little deserts next to them.

Little deserts may also occur next to a building, or other object that shelters the soil from precipitation. On the east side of a building you may find a narrow desert where the prevailing westerly winds have failed to wet the soil as they have on the west side of the building. Both plants and the animals on two sides of a building may be different in character because of the moisture in their microclimate.

Even the exposed surface of a rock may act as a little desert. Here rain washes away almost as it falls. Seeds that fall on exposed rock surfaces have a difficult time getting a foothold, unless they fall in cracks that hold enough moisture to cause germination. Usually only flat, hardy plants such as lichens are able to colonize a rocky surface. These unique plants, a combination of alga and fungus, can maintain a foothold on seemingly sterile rocky deserts. When the lichens have begun to erode the rock, and can hold some moisture in their plant bodies, mosses may be able to grow. Finally, bigger and more complex plants, with their associations of animals, may arrive on the scene to change the desert into a more temperate, humid climate.

Compare the little deserts around your home or school to other temperate areas in some of the following ways:

1. Soil hardness—test by seeing how far down you can push a pointed pencil with your palm. Is the desert soil hard, or is it looser than the soil of a grassy plot?
2. Porosity—cut the ends from a small juice can, push it down against the soil surface so no water can leak around the lower edges, and fill the can with water. Does it take longer for the water to seep away in desert soil or in a grassy plot?

The snowfall, too, is different under a tree. Snow often slides down the branches and drops on the ground in a ring around conifers such as spruces with their ski-slope shape. Near the trunk there may be little or no snow. Beneath the tips of the branches, the snow may be quite deep.

Because some trees catch rain or shed snow, the area under a dense crown may be a local desert. This is especially true of spruces and firs in winter, and of horsechestnuts, Norway maples, and hawthorns in summer. It is not so true of open-crowned trees such as elms.

To measure the difference in climate under the crown and outside the crown of a tree, set some rain gauges like that described on page 15 at different distances from the trunk, and place others in the open. Compare the rainfall caught in each gauge, and write these figures on a map of the area. A monthly record of the rainfall under and beyond a tree will give you a better record than measurements for a day or a week. By drawing lines to connect points of equal rainfall on your map, you can find where the precipitation is greatest.

Little mountains and valleys

On a small scale, but in a very real way, you can see some of the effects of mountains and valleys on the climate associated with them. A mountain may be as small as the ridge over a mole tunnel, or an ant hill. It may be so large that you must work to climb it. Whatever its size, the temperature on its north side may be very different from the temperature on its south side. The south slope of any small hill in the United States may receive almost direct sunlight, while the north slope receives only slanting rays from the sun. For this reason, the north slope of the smallest hill in your area is cooler than the south slope.

On page 22 is a picture of a footprint in soft soil. Snow collected in this footprint, but it melted on the south-facing slope. On the north-facing slope it remained as a tiny drift. Can you see from this tiny valley why ski slopes are almost always built on the north-facing slopes of hills? In the afternoon, when daytime temperatures are highest, the slope facing north will be facing away from the sun.

Road-cuts often show similar differences in snow cover. In winter, when you drive along a highway that is cut through a bank, look for a snow cover on the north-facing bank, even though the south-facing bank has none. Watch for deer feeding in the fields of the south-facing slopes, when the north-facing slopes are still snowbound. Watch for even the small scale, snowy slope on a lawn the day after a light snow when the sun comes out. A very light snow will melt quickly where the snow cover faces the sun, but

runoff of rainwater is slowed, the wind speed is almost zero, and there is dense shade under the grass. The soil is kept loose by the plant roots and by the burrowing animals that live there. Decay is rapid, the soil is rich in organic material near the surface, and the conditions are altogether different from the little desert on a path or at the edge of a building.

Using the same four methods of investigating these little climates, study the little jungles near the school building. Keep a record of these measurements and observations in order to compare the various little climates after you have studied each of them.

Under a tree

The crown of a tree acts as a radiation ceiling for the ground beneath it. When you stand under a tree during the daytime, you can

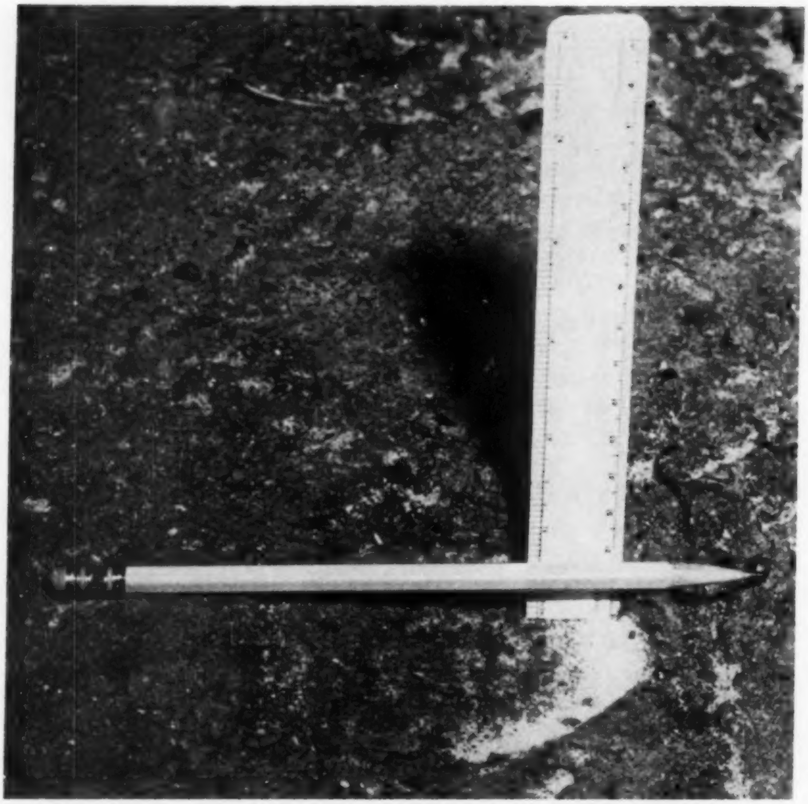
Beyond the crown of this campus tree, there is a heavy covering of frost on the grass.

feel how the tree cuts off the incoming radiation from the sun. At night, the outgoing radiation from the ground is also reduced. It is warmer under a tree at night, and cooler during the daytime because of the radiation ceiling formed by the tree crown.

On this page is a picture of frost that had formed on the Cornell University campus one autumn night. The grass all around the tree in the picture was white with frost. Under the tree, however, there was no frost on the grass, even though the tree had no leaves on it at the time. The branches alone interfered with the radiation from the ground, preventing its escape into space.

In addition to moderating temperature, a tree influences precipitation and wind. A light rain may never reach the ground beneath a tree; the raindrops are caught by the leaves. There they may evaporate unless it rains hard enough or long enough to drip from the leaves onto the ground.

Often, after it has rained for a long time and then stops, it will continue to drip under a tree. In this manner, the beginning and ending of a rainfall may be delayed beneath a tree when compared to the open. Besides, a tree shades the wet ground beneath it; the sun does not dry out the soil so quickly as in the open. By interfering with rainfall and sunlight, leafy branches make the climate beneath the tree quite different from that in the open.



This footprint was less than a half inch deep, yet it showed how snow will remain on a north-facing slope.

remain longer where it is tilted away from the sun. Sometimes you can look away from the sun and not see any snow on a lawn because the snowy slopes are parallel to your eye. When you look toward the sun, however, you may be conscious of a considerable snow cover because you are looking at north-facing slopes of many little ripples.

OTHER FEATURES OF MICROCLIMATES

Mirages

In driving along a highway on a hot sunny day, the pavement far ahead often looks wet, especially where the road is flat. This mirage is more noticeable over blacktop roads than over concrete highways,

because blacktop gets hotter than light-colored pavement.

As air becomes warm, its density or heaviness diminishes. Light passes more easily through such air than through cold heavy air. When the air next to the pavement is hotter than the air above it, the light passing through this air bends upward away from the pavement. A mirage is formed when light from the sky angles down toward the pavement, bends as it nears the road surface, and continues toward an observer's eyes. The seeming wetness on the road is really light from the sky above the road.

The picture below shows a mirage on a section of highway in New York State. Notice how the light from the sky is bent so that a bit of sky seems to rest on the pavement. When you see mirages on the highway, watch oncoming cars, road signs, and guard rails closely. They may be visible in the upper part of the mirage, but lost altogether in the lower part.

What looks like a puddle of water in this mirage is only light from the sky that has been bent by the hot air next to the pavement.

Dew

You have learned that radiation from the earth's surface takes place constantly, and that things on the earth begin to cool when the incoming radiation is less than the outgoing radiation. As objects cool, the air touching them cools, too. If the temperature of the air next to them drops far enough, the moisture in the air will condense on the radiating objects. Then they become wet from dew.

Cooled air becomes heavy and sinks to the ground; therefore, dew is more apt to form near the ground than far above it. Some of the air that cools on a radiating roof flows down the roof and sinks to the ground where further cooling takes place. Air that is near the top of a sloping hillside slowly flows downhill as it cools, and collects in a shallow pool or puddle in the hollows. There, it cools still further as the grass and soil radiate heat to space. For this reason, dew is much heavier in the hollows than on a hilltop, or on a slope.

Although dew forms because the objects near the surface lose some of their heat to space, dew also helps prevent excessive heat loss. A little heat is put back into the air and into the objects when the dewdrops form. Heat is needed to evaporate water. You can see that much heat is required to evaporate water in a pan on the stove. Water droplets that remain on your skin after swimming take heat from your body when they evaporate, and this cools you.

Conversely, when water droplets form again from water vapor, they give off the heat that was needed to evaporate them in the first place. Cooling must occur for dew to form, but the dew that forms also slows the cooling process somewhat.

Sometimes the presence of a sort of ceiling above the radiating objects prevents the loss of energy to space, and the radiating object does not cool below the dewpoint. Trees form very effective barriers to radiation from the ground beneath them. An overhanging roof, a cloud, or even a piece of cheesecloth above an object forms an effective barrier or ceiling to the outgoing radiation.

On page 20 you saw a picture of just how effective a single tree is in preventing radiational cooling of the objects beneath its crown. The grass all around the tree was well frosted because of the cooling that took place during the night. Under the tree, however, there was almost no frost because the leaves and branches prevented the radiation from leaving that space.

Radiation ceilings absorb some of the outgoing radiation, then radiate it right back where it came from. Radiation ceilings such as trees cannot prevent all the energy from leaving, but they prevent much of it from escaping.

Flagstones in a walk do not always show dew formation even


Just as the heat conducted by flagstones inhibits dew formation, it speeds the melting of snow that falls on them.

when the grass becomes very wet with dew, partly because the stones are flat against the soil, and partly because they are better conductors of heat than grass. The heat they lose by radiation is replaced by more heat from the soil below. This helps to keep the stones from cooling as rapidly as the grass around them.

Car tops are quick to become wet with dew, even though they are metal and are good conductors. Because they are so far above the soil and are insulated by rubber tires and by the air inside the car, they cannot get more heat to replace what they lose.

Dark-colored objects tend to radiate faster at night than do light-colored objects. Observe the roof of a dark car and a light car on a clear night and see which shows the formation of dew sooner. Can you see that the black top is a better radiator, and cools faster than the light top?

The pattern of the dew that forms on the hood and the trunk lid of cars is also interesting. On the trunk there are steel braces to support the metal lid. These braces can supply a little additional heat to the radiating metal above them, but not so much to the thin metal sheet be-

tween the braces. For this reason, dew sometimes forms on the trunk between the braces, but not directly over the braces themselves. Look for patterns in the dew on the hoods and on the trunks of cars to see if you can tell where braces or insulation are located.

Just as car tops are well insulated from the soil beneath them, bridges are insulated from the banks on which they stand. The road bed of a bridge radiates heat at night, but is so far from the soil on either side that the heat it loses is not replaced by heat from the banks that support it. As a result, bridge pavement is often wet with dew when the road that leads to the bridge is dry.

The wooden planks between rails at some railroad crossings may become wet with dew, while the road leading to the crossing may be dry. These planks, made of wood, are not good conductors of heat. When their upper surfaces lose heat to the clear night sky, little additional heat passes through the wood from below. The plank surfaces continue to cool, even though the soil under them may be much warmer than the upper part of the planks themselves.

When you see dew on grass, on car tops, on boards, or on your tent, try to figure out why it formed where it did. Was the sky clear, and the wind nearly calm, and was the dewy surface where it could not get heat from the soil below it?

Frost

The conditions that cause dew to form are like those that cause frost to form. Clear skies, light winds, and a surface that will radiate heat without having it replaced by more heat from the soil all help to form frost. *Frost is not frozen dew,* however. The temperature of the radiating object must fall below freezing before frost forms.

A simple activity will help you see that frost forms without dew forming first. Hold a small carbon dioxide cartridge in a gloved hand (the glove insulates the fingers against the cold) while you puncture the end of the cartridge with a phonograph needle, or with a tool sold in toy shops for the purpose. As the carbon dioxide gas escapes, and the pressure in the cartridge decreases, the surface of the metal cartridge cools rapidly. Soon after the temperature drops below freezing, you can see a white coating of frost begin to form on the outside. This white coating is not preceded by a covering of water droplets that freeze. The coating is real frost. The melted frost will be water, but first it forms ice, not water.

Like dew, frost gives off a little heat when its ice crystals form. Cooling must take place for frost to form, but the formation of the frost itself slows the cooling process.

Frost forms more readily on ridges than it does in little grooves or hollows. The picture on page 27 shows frost that formed on some leaves of

Can you find frost on the veins of other plants besides mustard? Where does it form on blades of grass?

mustard. The leaves had fallen to the ground with their veins turned toward the sky. The veins represented tiny ridges and these radiated their heat out to space more effectively than did the depressions between veins. If these had been the size of hills and valleys, perhaps the cooler air from the hilltops would have moved down into the valleys and there the frost would have been heavy. On a scale as small as a leaf vein, however, air drainage is less important than the direct cooling of air in contact with the vein.

If you examine the distribution of frost on a cold, clear morning, you may see that the crystals are heaviest where the surface is ridged or pointed. Even tiny galls that project from a leaf surface frost over more quickly than flat or hollowed surfaces. The tiny galls stand up and their outgoing radiation is unhindered by surfaces around them. Little depressions do not frost so quickly because their outgoing radiation is hindered by higher surrounding surfaces.

When windshield wipers run back and forth across the glass, they

Look at your own car windows when there is a frost. Can you see where the wipers or your chamois passed over the glass?

make tiny scratches and ridges in the glass. These may be too small for you to see with your naked eye, but on a frosty night you can tell where the scratches are by the frost that forms there. The side windows of a car, too, may be scratched as they are moved up and down in the doors. Frost will form in streaks on these windows, showing where the scratches are.

Observe frost patterns to see if you can tell how well a surface radiates, or where the tiny ridges and hollows must be. Can you tell why a car parked under a tree probably will not become frosty, when one parked in the open may be white with frost on top, or on the surfaces that face upward?

Fog

Fogs of the microclimate may form in two ways. *Steam fog* forms when water evaporates from a wet surface that is warmer than the air above it. When the water vapor mixes with the cooler air above, it condenses to form fog. Steam fog often forms over a hot highway in summer when a shower is too brief to cool the road. After the shower, the highway steams as water vapor condenses in the air just above it.

Steam fogs also may form over ponds in summer. When the night is clear, the air cools rapidly but the pond remains warm. By early morning, water vapor from the pond may condense in the air above the

water surface so that the pond appears to steam.

In winter similar steam fogs may form when cold Arctic air blows across lakes that are not frozen. Although more extensive than the summer steam fogs over farm ponds, these fogs occur under the same conditions—warm water covered by much colder air.

Unlike steam fog, *radiation fog* may form over a land surface far from water. It results from the extreme cooling of air in depressions when skies are clear and winds are light. If the air that settles in the depression is moist, and cooling takes place through a depth of several feet rather than just at the surface of soil and grass, fog often forms. Radiation fog is usually shallow, and sometimes you can see the sky clearly through it, even though it may extend for some distance horizontally.

In a flat valley near Cortland, New York, the radiation fog commonly occurs only to a depth of five to 10 feet—enough to make driving hazardous—but may extend a mile or more sideways. A person walking in this radiation fog may not be able to see a tree a short distance in front of him, but he can look up through the shallow fog and see the sky clearly.

Pilots sometimes are bothered by radiation fogs that do not obscure the airfield when the plane is directly overhead, but do obscure it when the pilot begins his descent. Then he must look through a greater distance of fog than he did from above.

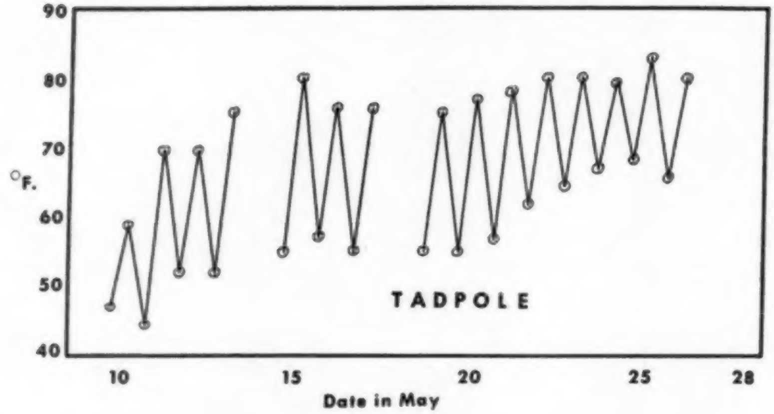
Watch for steam fogs and radiation fogs near your home or school. When there is a steam fog, take the temperature of both the water surface and the air a foot or so above it. What is the difference in the two temperatures?

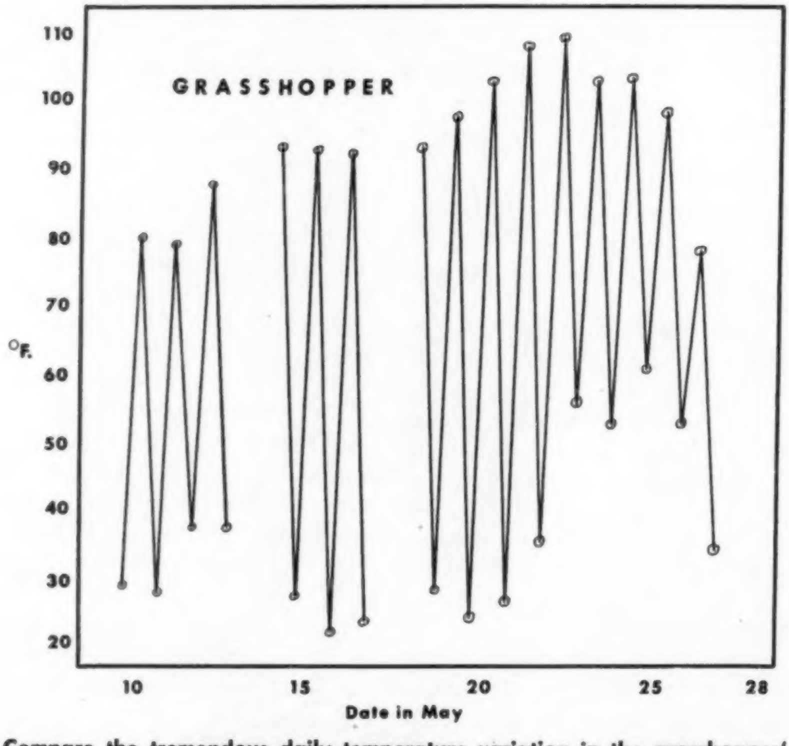
If a radiation fog occurs, check the temperature in the fog and compare it with the temperature on the hillside above the fog. Can you see that both kinds of fog form where the temperature of the air is low?

THE MICROCLIMATE OF LITTLE ANIMALS

The graph on page 30 shows the temperatures measured in a meadow near Ithaca during the month of May. Residents thought this was a very nice month with seasonable temperatures. On a single day, however, the temperature ranged from 27° F. to 104° F.! If these had been official Weather Bureau temperatures, it would have made history in Ithaca. Fortunately, these temperatures were measured at the surface of a meadow where crickets, grasshoppers and ants lived.

Compare the two graphs on page 30. One represents the highest and lowest temperatures of each day one inch above the soil in a meadow where grasshoppers were abundant. The other represents the highest





Compare the tremendous daily temperature variation in the grasshopper's microclimate with the slight variation in that of the toad tadpole.

and lowest temperature of each day in a nearby pond where toad tadpoles were growing. Note how much greater was the temperature range of the meadow microclimate than of the pond microclimate.

Microclimates may differ greatly in moisture also. The microclimate of spiders, slugs, snails, and millipedes is very moist. When the sun shines, they must retreat to the recesses under logs, stones, bark, and roots. The grasshopper's microclimate is sunny, hot, dry, and sometimes windy. A single meadow may provide both extremes, one at the grasstops or soil surface, and the other in the recesses under roots, stones, and debris. Probing with a thermometer will help you find some of the different microclimates available to the animals living around you.

The wind in the microclimate often is as important as the temperature and the humidity. Some animals that have adaptations for withstanding extremes of temperature must still rely on air movements to bring them scents of food and danger. The mouse or chipmunk may sniff the air very close to the ground, the rabbit sniff the air a little higher, and the deer sniff the air three or four feet above the ground. Because the wind may blow from different directions at these levels (see page 13), one animal may sense danger and the others may not.

Some small animals have interesting adaptations to help them live successfully in their microclimates. Those that are not so well adapted must withstand the rigors of the microclimate, or move to another. The light-colored skins of some lizards help to reflect the intense heat from the sun. Some have feet adapted to running over very hot sand. Some insects that fly near the ground during the daytime slowly rise in swarms at night as cool air from hillsides fills depressions. Some snails seal their shells with a layer of mucous to prevent evaporation in the daytime or during a drought. Earthworms move up or down in the soil as temperature and moisture change. The red-backed salamander retires to the moist soil under a rotting log during the heat and dryness of the day. How many other adaptations or habits can you find among small animals that help them meet the rigors of their microclimate?

As you study microclimates, remember that there are cool ones not far from hot ones, and moist ones not far from dry. The temperature at your feet is not measured by a thermometer at eye level, nor is your climatic comfort any indication of the rigors in the grass. Microclimates are interesting in themselves, but they are even more so when you consider their importance to the creatures that live in them.

SOME REFERENCES FOR THE TEACHER

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FRANKLIN T. BEDFORD, CLIMATES IN MINIATURE, *Philosophical Library, New York, 1955. 134 pages.* Written for a British audience, this little book has some interesting and appropriate descriptions of the effect of microclimates on plants and animals of the garden. It presents just enough data to be convincing, but not stuffy.

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ROCKCASTLE, V. N., "LITTLE CLIMATES", THE INSTRUCTOR, *Owen Publishing Co., Dansville, New York, 1959. Vol. 69, No. 2, pages 34–35, 64, and 78.* This article suggests simple activities for primary and intermediate grade children to help interest them in, and introduce them to, the climate near the ground.